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Computed tomography of the thorax of calves from birth to the age of 105 days

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Abstract: The present study was undertaken to provide computed tomographic (CT) reference values for structures in the thorax of the calf. Six clinically healthy Holstein-Friesian calves were anaesthetized. Transverse pre- and postcontrast images with a reconstructed 1.5-mm slice thickness were obtained using a multislice-CT scanner at 6 different time points from birth to 105 days of age. Absolute and relative measurements of the trachea, heart, cranial and caudal vena cava, thoracic aorta, right and left principal bronchi, right and left caudal lobar bronchi and the accompanying branches of the right and left pulmonary artery and vein, thoracic lymph nodes and lung density were taken for every time point. All animals were euthanized after the last CT scan, and 4 calves were frozen to generate an atlas comparing gross anatomy with CT. During the study, 4 animals temporarily showed coughing and mucopurulent nasal discharge, and mild to moderate bronchopneumonia and pleuritis were diagnosed using CT. Animals recovered with treatment; however, mild to moderate CT changes remained throughout the study. Even in the 2 clinically normal animals, mild bronchopneumonia was diagnosed on CT.

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Table 1: Descriptive statistics of thoracic measurements in 6 clinically normal calves of 6 consecutive CT examinations 3 weeks apart [mean, standard deviation (minimum-maximum)]; CSA: cross-sectional area; *first measurement which was significantly different from first CT scan: $p < 0.05$)

Variable	CT scan					
	Scan 1 (1-2 days old)	Scan 2 (21 days old)	Scan 3 (42 days old)	Scan 4 (63 days old)	Scan 5 (84 days old)	Scan 6 (105 days old)
Thoracic height at T1 (cm)	11.5, 0.78 (10.5 – 12.6)	12.2, 0.47 (11.5 – 12.8)	13.2, 0.87 (11.9 – 13.9)*	13.9, 1.0 (12.5 – 15.5)	14.5, 1.2 (12.5 – 15.8)	15.8, 1.6 (13.4 – 18.4)
Thoracic height at T4 (cm)	14.8, 1.53 (12.7 – 16.9)	16.9, 0.89 (15.3 – 17.8)*	19.1, 1.36 (16.8 – 20.4)	19.5, 0.79 (19.1 – 21.3)	20.7, 1.33 (18.3 – 21.9)	21.7, 1.07 (19.9 – 22.7)
Thoracic height at T8 (cm)	16.0, 1.33 (14.1 – 17.5)	18.2, 1.06 (17.2 – 19.7)*	20.5, 0.6 (19.6 – 21.1)	21.2, 0.89 (20.2 – 22.0)	23.1, 0.66 (22.7 – 23.6)	23.4, 0.32 (23.2 – 23.7)
Thoracic width at T1 (cm)	6.0, 0.44 (5.3 – 6.4)	6.1, 0.43 (5.2 – 6.4)	6.7, 0.43 (5.9 – 7.0)*	7.1, 0.47 (6.3 – 7.5)	7.3, 0.53 (6.4 – 7.8)	7.4, 1.04 (6.2 – 9.4)
Thoracic width at T4 (cm)	9.9, 0.65 (9.2 – 10.7)	11.1, 0.38 (10.5 – 11.6)*	12.9, 2.06 (10.7 – 16.3)	13.6, 1.28 (12.0 – 15.0)	15.6, 2.84 (12.3 – 18.9)	18.4, 3.8 (13.8 – 22.2)
Thoracic width at T8 (cm)	12.9, 1.02 (11.3 – 14.2)	15.0, 0.77 (14.1 – 15.9)*	17.9, 1.41 (16.1 – 19.8)	20.8, 2.65 (18.3 – 25.3)	27.2, 6.21 (19.6 – 36.9)	29.7, 5.21 (24.6 – 35.9)
Cardiac width (cm)	9.7, 0.83 (9.1-11.2)	10.9, 0.74 (9.6-11.8)*	11.8, 0.37 (11.3-12.3)	12.2, 0.62 (11.2-12.9)	12.0, 1.21 (10.0-13.6)	12.6, 0.44 (12.2-13.4)
Cardiac height (cm)	14.4, 0.91 (13.6-16.1)	15.1, 0.67 (13.9-16.0)	15.3, 0.59 (14.2-15.9)	16.7, 1.65 (13.9-18.9)*	15.9, 1.16 (14.4-17.3)	17.2, 0.58 (16.1-17.7)
Vertebral heart score (VHS)	9.3, 0.3 (9.0-10.0)	9.3, 0.24 (9.0-9.5)	9.1, 0.21 (9.0-9.5)	8.8, 0.22 (8.5-9.0)*	7.9, 0.49 (7.5-9.0)	8.2, 0.27 (8.0-9.0)
Maximal height of aorta (cm)	1.7, 0.21 (1.4-2.0)	2.0, 0.19 (1.7-2.2)*	2.1, 0.1 (2.0-2.3)	2.4, 0.22 (2.0-2.6)	2.6, 0.26 (2.2-2.9)	2.7, 0.31 (2.4-3.2)
Maximal height of cranial vena cava (cm)	1.7, 0.21 (1.75-2.0)	1.9, 0.24 (1.5-2.2)	2.1, 0.21 (1.7-2.3)*	2.2, 0.22 (1.0-2.5)	2.3, 0.34 (1.7-2.6)	2.3, 0.28 (1.8-2.6)
Maximal height of caudal vena cava (cm)	2.0, 0.27 (1.7-2.5)	1.8, 0.42 (1.4-2.4)	1.8, 0.12 (1.6-2.0)	2.1, 0.2 (1.2-2.5)	1.8, 0.27 (1.4-2.1)	2.0, 0.25 (1.7-2.4)
Maximal height of caudal vena	1.2, 0.14 (1.0-1.4)	0.9, 0.18 (0.7-1.2)*	0.8, 0.07 (0.7-0.9)	0.9, 0.24 (0.5-1.2)	0.7, 0.08 (0.6-0.8)	0.8, 0.15 (0.5-0.9)

cava/aorta						
Maximal height of caudal vena cava/length of vertebra at the level of the bifurcation of the trachea	0.8, 0.11 (0.7-1.0)	0.7, 0.15 (0.5-0.9)*	0.6, 0.06 (0.6-0.7)	0.6, 0.14 (0.4-0.8)	0.5, 0.09 (0.4-0.6)	0.6, 0.09 (0.5-0.7)
Tracheal height at thoracic inlet (cm)	2.0, 0.22 (1.8-2.4)	2.3, 0.32 (1.9-2.7)	2.3, 0.27 (1.9-2.6)	2.3, 0.32 (1.9-2.8)	2.3, 0.33 (1.8-2.7)	2.7, 0.33 (2.3-3.3)*
Tracheal width at thoracic inlet (cm)	2.0, 0.19 (1.7-2.2)	2.0, 0.21 (1.8-2.4)	2.1, 0.08 (2.0-2.2)	2.1, 0.25 (1.6-2.3)	2.0, 0.17 (1.8-2.3)	2.4, 0.26 (2.1-2.7)*
CSA of trachea at thoracic inlet (cm ²)	3.3, 0.48 (2.7-4.2)	3.9, 0.81 (3.1-5.4)	4.0, 0.79 (2.8-5.0)	4.0, 0.99 (2.6-5.3)	3.7, 1.28 (2.4-5.4)	5.3, 1.3 (3.6-7.5)*
CSA of trachea at bifurcation (cm ²)	3.1, 0.79 (2.1-4.4)	3.7, 0.92 (2.4-5.2)	3.8, 0.62 (3.1-4.6)	4.0, 0.59 (3.4-5.0)*	4.2, 0.82 (3.5-5.7)	5.3, 1.5 (4.0-8.0)
Tracheal height/thoracic height at thoracic inlet	0.18, 0.01 (0.17-0.19)	0.19, 0.02 (0.17-0.22)	0.18, 0.02 (0.13-0.19)	0.16, 0.02 (0.12-0.19)	0.16, 0.02 (0.12-0.18)	0.17, 0.02 (0.14-0.19)
Outer CSA of right principal bronchus (cm ²)	1.8, 0.4 (1.4-2.3)	2.6, 0.5 (2.0-3.5)*	2.9, 0.42 (2.9-4.2)	3.7, 0.71 (2.7-4.6)	4.0, 0.49 (3.2-4.5)	4.3, 0.89 (3.5-6.0)
Inner CSA of right principal bronchus (cm ²)	1.2, 0.29 (0.8-1.5)	1.5, 0.38 (1.2-2.2)	2.0, 0.41 (1.6-2.7)*	1.9, 0.45 (1.2-2.4)	2.2, 0.32 (1.6-2.6)	2.3, 0.72 (1.6-3.7)
CSA of wall of right principal bronchus (cm ²)	0.6, 0.11 (0.5-0.8)	1.1, 0.26 (0.7-1.5)*	1.4, 0.09 (1.3-1.5)	1.7, 0.3 (1.3-2.2)	1.8, 0.29 (1.5-2.3)	2.0, 0.37 (1.5-2.4)
Outer CSA of left principal bronchus (cm ²)	1.7, 0.39 (1.3-2.3)	2.4, 0.7 (1.9-3.8)	3.3, 0.8 (2.3-4.3)*	3.1, 0.72 (2.2-4.3)	3.9, 0.69 (3.0-4.6)	4.0, 1.16 (2.6-5.7)
Inner CSA of left principal bronchus (cm ²)	1.1, 0.26 (0.81-1.4)	1.5, 0.5 (1.0-2.7)	1.9, 0.5 (1.3-2.7)*	1.7, 0.43 (1.0-2.2)	2.2, 0.5 (1.1-2.6)	2.2, 0.68 (1.6-3.8)
CSA of wall of left principal bronchus (cm ²)	0.6, 0.16 (0.4-0.9)	0.8, 0.18 (0.6-1.1)*	1.3, 0.36 (0.9-1.8)	1.4, 0.3 (1.2-2.1)	1.9, 0.35 (1.3-2.1)	1.7, 0.49 (0.94-2.2)
Interbronchial angle (°)	41.1, 3.6 (36.1-46.5)	42.0, 4.7 (35.2-47.4)	47.7, 7.9 (37.8-61.1)	49.2, 7.0 (38.3-58.6)*	58.0, 12.6 (41.2-75.6)	63.7, 8.7 (51.2-73.3)
Inner CSA of left caudal lobar bronchus (cm ²)	0.6, 0.14 (0.4-0.8)	0.3, 0.09 (0.2-0.4)*	0.4, 0.17 (0.1-0.6)	0.4, 0.09 (0.3-0.5)	0.4, 0.16 (0.2-0.6)	0.5, 0.15 (0.3-0.8)
CSA of caudal lobar branch of left	0.5, 0.13 (0.4-0.8)	0.3, 0.04 (0.2-0.4)*	0.4, 0.16 (0.2-0.7)	0.6, 0.19 (0.4-0.9)	0.5, 0.23 (0.3-0.8)	0.6, 0.12 (0.4-0.8)

pulmonary artery (cm ²)						
CSA of caudal lobar branch of left pulmonary vein (cm ²)	0.6, 0.21 (0.3-1.0)	0.3, 0.06 (0.2-0.4)*	0.5, 0.15 (0.2-0.7)	0.5, 0.15 (0.3-0.7)	0.5, 0.28 (0.2-0.9)	0.6, 0.15 (0.4-0.7)
Inner CSA of right caudal lobar bronchus (cm ²)	0.7, 0.14 (0.5-0.8)	0.3, 0.14 (0.2-0.5)*	0.4, 0.2 (0.2-0.7)	0.4, 0.11 (0.2-0.5)	0.5, 0.16 (0.2-0.7)	0.5, 0.2 (0.3-0.8)
CSA of caudal lobar branch of right pulmonary artery (cm ²)	0.7, 0.23 (0.5-1.1)	0.4, 0.26 (0.2-0.9)*	0.5, 0.21 (0.3-0.8)	0.5, 0.13 (0.4-0.7)	0.5, 0.13 (0.4-0.7)	0.7, 0.16 (0.4-0.8)
CSA of caudal lobar branch of right pulmonary vein (cm ²)	0.7, 0.13 (0.5-0.9)	0.5, 0.4 (0.2-1.4)*	0.5, 0.22 (0.3-0.7)	0.5, 0.2 (0.3-0.7)	0.5, 0.21 (0.3-0.9)	0.7, 0.3 (0.3-1.0)